



UVOT Analysis Software and Data Products

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Who are we?



- ❑ SSC = Swift Science Center.
- ❑ Primarily we are the two-way information highway between the Swift Team and the community (SSC talk by Stephen Holland today).
- ❑ The SSC is not a member of the UVOT instrument team.
- ❑ UVOT software is being developed by the SSC at NASA Goddard Space Flight Center, close to the HEASARC, FTOOL developers, Swift SDC and the BAT team.



Outline



- TDRSS message data & software
- Malindi data & software
- Burst Advocate software



Note



- ❑ The ideology behind UVOT software development has been to convert raw telemetry to generic data products which are readily readable by your favourite analysis packages.
- ❑ In particular, your high-level analysis can be achieved using the HEASoft main-stays XIMAGE, XSELECT, XRONOS, and XSPEC.
- ❑ The vast majority of UVOT software will rarely/never have to be used by YOU for science analysis.



TDRSS Data and Software



TDRSS and GCN messages



- ☐ Two distinct messages are sent through the TDRSS system from UVOT to the GCN (GRB Coordinates Network). They are derived onboard from the 100-s V filter finding chart exposure.
 1. **sparse finding chart message**
 - ☐ sent 243-s after settling
 2. **Gamma-ray burst Neighbourhood Image (GeNle)**
 - ☐ sent shortly(?) afterwards
- ☐ Products derived from the TDRSS messages will be communicated by email to GCN subscribers.



Sparse finding chart message



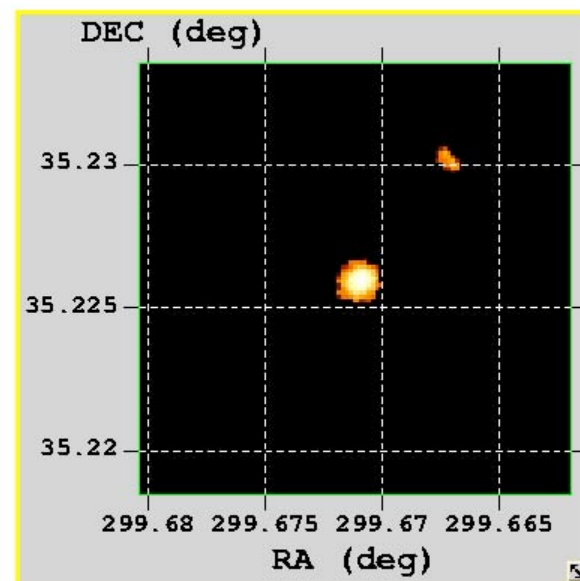
- ☐ An on-board Algorithm detects sources in the field.
- ☐ Spacecraft transmits a table, containing detector locations and count rates from incomplete samples of pixels around each source.
- ☐ The on-board algorithm is not sophisticated:
 - ☐ Source list may be incomplete if the field is crowded.
 - ☐ Source list may contain spurious sources from:
 - ☐ Extended sources
 - ☐ Saturated point sources
 - ☐ Background spikes
 - ☐ Stray light
- ☐ Aim of the UVOT software is to convert this raw list into readable products that allow both machine and humans to identify afterglow candidates.



GeNle image



- ❑ An 80x80 pixel image from the 100-s V filter finding chart exposure.
 - ❑ If an XRT position is known, the image will be binned 1x1; with a window size of 0.63x0.63 arcmin.
 - ❑ if an XRT position is not transmitted, the image will be binned 8x8; with a window size of 5x5 arcmin.
- ❑ Primary function of the GeNle is to test the fidelity of the sparse finding chart message.





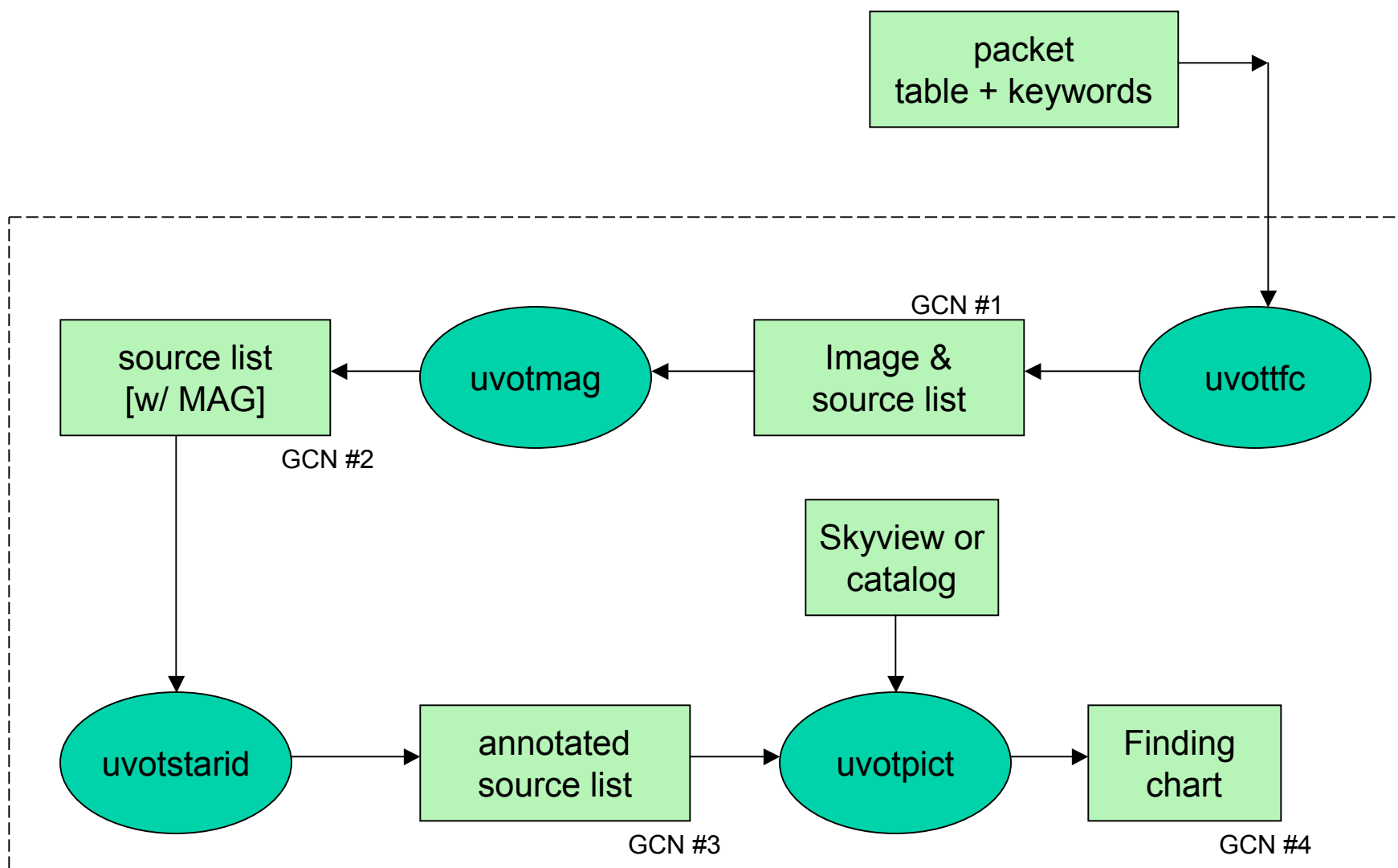
GCN messages



- ❑ Messages from the GCN are:
 - ❑ Sparse finding chart:
 - ❑ GCN #1 Sky image reconstructed from source positions.
 - ❑ GCN #2 List of sources with RA, Dec and magnitude.
 - ❑ GCN #3 List of detected sources cross-correlated with GSC.
 - ❑ GCN #4 Finding chart with XRT & BAT error circles.
 - ❑ GeNle image:
 - ❑ GCN #5 Sky image.
 - ❑ GCN #6 List of sources with RA, Dec and magnitude.
 - ❑ GCN #7 List of detected sources cross-correlated with GSC.
 - ❑ GCN #8 Finding chart with XRT & BAT error circles.

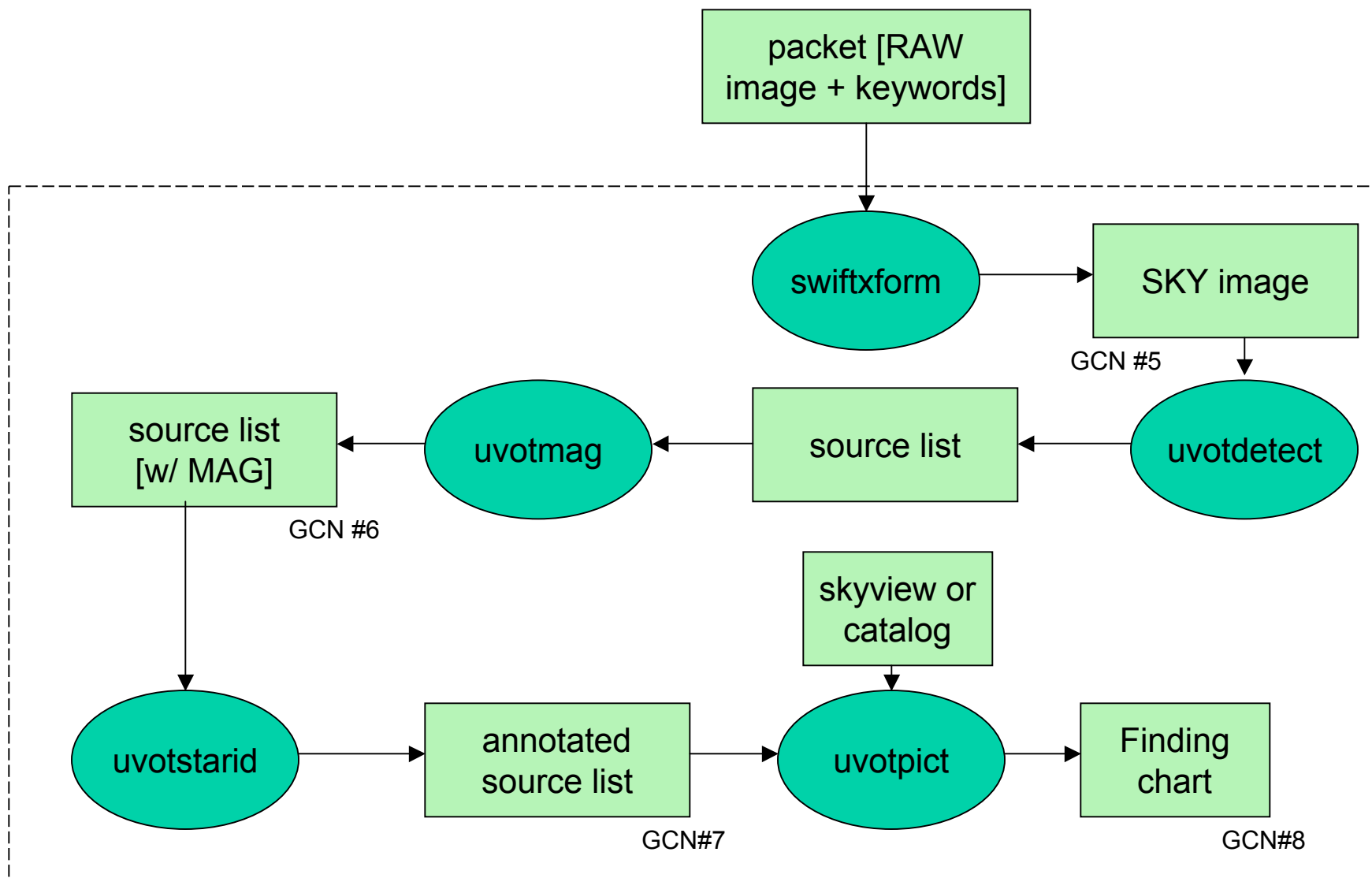


sparse finding chart processing





GeNle image processing





GCN source list



| | | | | | | | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| fv: Binary Table of uvot_analst_fchart.fits[1] in /local/data/still/Swift/UVOT/sw00000001001.021/tdrss/ | | | | | | | | | | | |
| File Edit Tools Help | | | | | | | | | | | |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| REFID | STARID | RA | DEC | MAG | TYPE | PACKET | CAT_DELTA | MAG_DELTA | XRT_DELTA | BAT_DELTA | |
| I | 16A | D | D | E | 12A | 12A | E | E | E | E | |
| | | deg | deg | | | | arcsec | | arcsec | arcsec | |
| 1 | 1 | NULL | 23.3501 | -41.8229 | 15.16 | NULL | 5x5 stamp | NULL | NULL | 1.38 | 1.38 |
| 2 | NULL | 10308 | 23.3508 | -41.8290 | 0.00 | non-star | NULL | NULL | NULL | 21.34 | 21.34 |
| 3 | 6 | 9281 | 23.3435 | -41.8280 | 15.89 | non-star | 5x5 stamp | 0.04 | -0.51 | 24.13 | 24.13 |
| 4 | NULL | 9265 | 23.3512 | -41.8313 | 21.52 | non-star | NULL | NULL | NULL | 29.87 | 29.87 |
| 5 | 14 | 9304 | 23.3668 | -41.8181 | 17.63 | star | 5x5 stamp | 0.10 | -0.58 | 49.10 | 49.10 |
| 6 | 20 | 9247 | 23.3512 | -41.8400 | 18.05 | non-star | 5x5 stamp | 0.52 | -0.57 | 60.14 | 60.14 |
| 7 | 24 | 8442 | 23.3838 | -41.8234 | 18.54 | star | 5x5 stamp | 0.76 | -0.62 | 90.64 | 90.64 |
| 8 | 5 | 15 | 23.3314 | -41.8004 | 14.14 | non-star | 5x5 stamp | 0.24 | -0.80 | 95.74 | 95.74 |
| 9 | 3 | 86 | 23.3362 | -41.7968 | 13.92 | non-star | 5x5 stamp | 0.33 | -0.85 | 102.31 | 102.31 |
| 10 | 12 | 9326 | 23.3135 | -41.8052 | 17.20 | star | 5x5 stamp | 0.85 | -0.61 | 117.81 | 117.81 |
| 11 | 11 | 8588 | 23.3701 | -41.7933 | 17.18 | star | 5x5 stamp | 0.28 | 17.18 | 120.89 | 120.89 |
| 12 | 4 | 19 | 23.3050 | -41.8361 | 14.14 | star | 5x5 stamp | 0.06 | -0.83 | 128.82 | 128.82 |
| 13 | 18 | 9266 | 23.2968 | -41.8330 | 18.03 | star | 5x5 stamp | 0.62 | -0.55 | 146.48 | 146.48 |
| 14 | 10 | 8358 | 23.4000 | -41.8418 | 17.19 | star | 5x5 stamp | 1.13 | -0.48 | 149.05 | 149.05 |
| 15 | 19 | 9292 | 23.2931 | -41.8235 | 18.00 | star | 5x5 stamp | 0.43 | -0.58 | 151.77 | 151.77 |
| 16 | 27 | 9288 | 23.2886 | -41.8244 | 19.11 | non-star | 5x5 stamp | 0.79 | -0.24 | 163.36 | 163.36 |
| 17 | 8 | 9360 | 23.2932 | -41.7904 | 17.02 | star | 5x5 stamp | 0.65 | -0.43 | 192.90 | 192.90 |
| 18 | 7 | 9369 | 23.2972 | -41.7867 | 15.91 | star | 5x5 stamp | 0.51 | -0.52 | 193.46 | 193.46 |
| 19 | 15 | 9388 | 23.3068 | -41.7798 | 17.83 | non-star | 5x5 stamp | 1.16 | -0.33 | 193.87 | 193.87 |
| 20 | 23 | 8436 | 23.4320 | -41.8236 | 18.68 | non-star | 5x5 stamp | 0.42 | -0.74 | 220.67 | 220.67 |

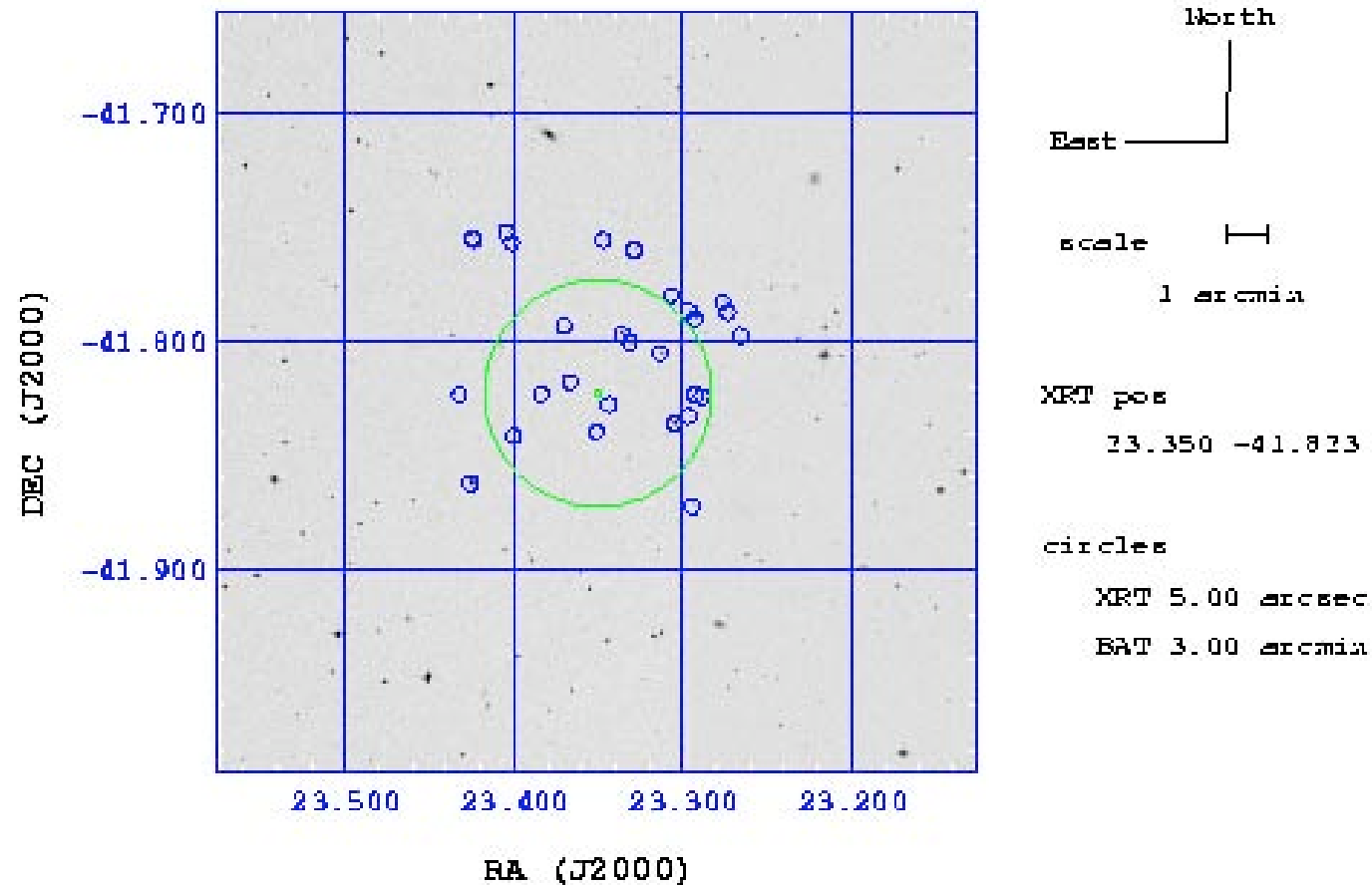
Go to: Edit cell:



sparse finding chart message *Swift*

UVOT Finding Chart

OBSID 00000001001 / DATE-OBS 2003-12-19T15:30:40.6





Malindi Data and Software



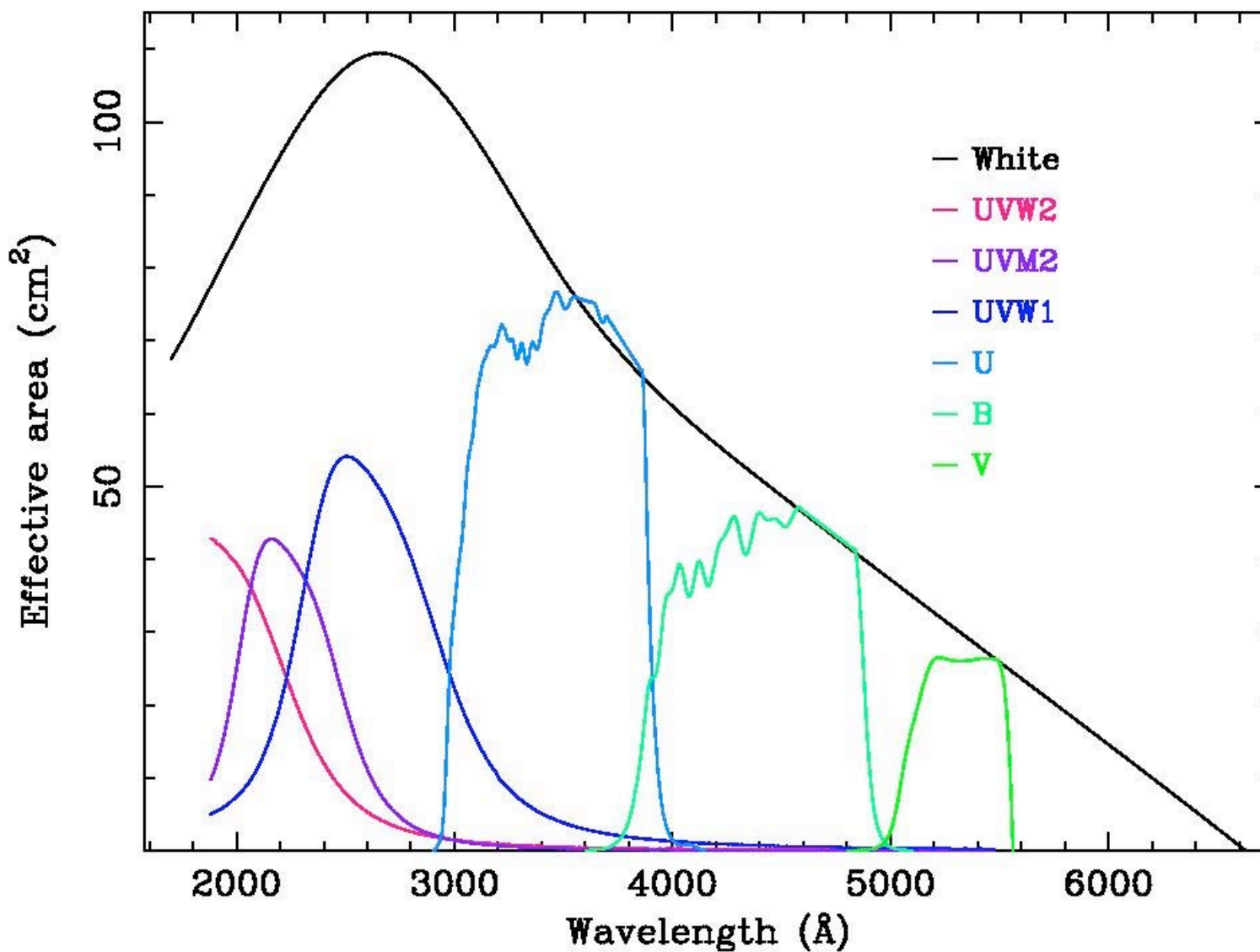
Software products



- ☐ The goal of UVOT pipeline processing is to provide data products on two levels:
 - ☐ Level II:
 - ☐ Series of images, exposure maps and event tables that are compatible with your favourite analysis tools. These will be the starting point for all of your high-level data analysis.
 - ☐ Level III
 - ☐ Higher level products. The quality of some of these products must always be verified by yourselves.
 - ☐ deep, co-added images
 - ☐ source lists
 - ☐ light curves
 - ☐ grism spectra
 - ☐ gif plots

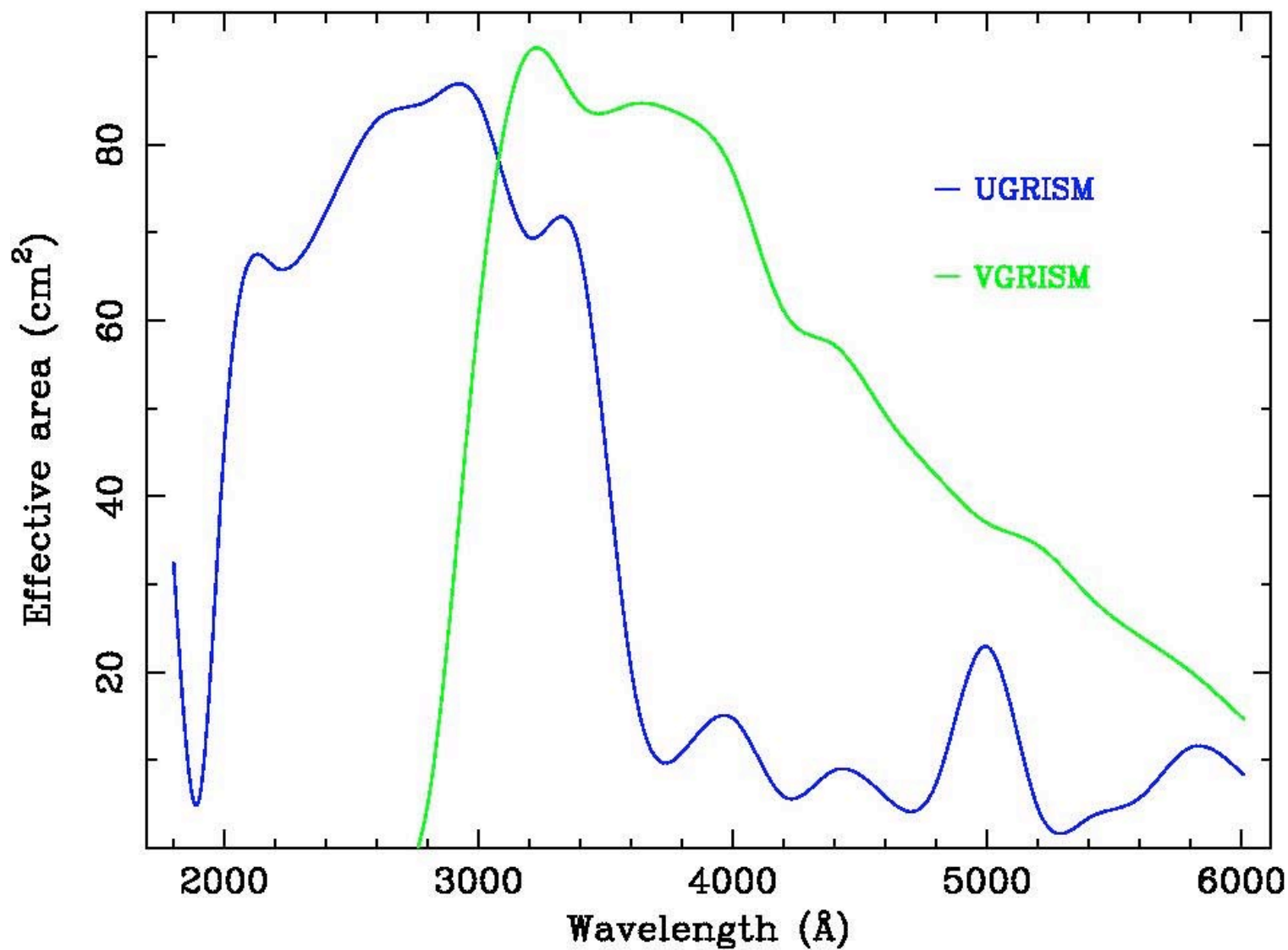


UVOT broad band effective areas





UVOT grism effective areas





data modes



- ☐ Imaging mode
 - ☐ 1x1, 2x2, 4x4 and 8x8 binned images are possible.
 - ☐ The image can be windowed onboard to any subset of the 2048x2048 full frame.
 - ☐ More than one combination of binning and windowing will occur during a single observing sequence.
- ☐ Event mode
 - ☐ 1x1 binning always.
 - ☐ Any detector window is possible.
 - ☐ Event timing will be good to 11 ms, regardless of window size and binning.
- ☐ Image&Event mode
 - ☐ Imaging and Event data obtained simultaneously.
 - ☐ Binning and windowing may differ between the two modes.
 - ☐ 1x1 event binning always.



Typical observing sequence

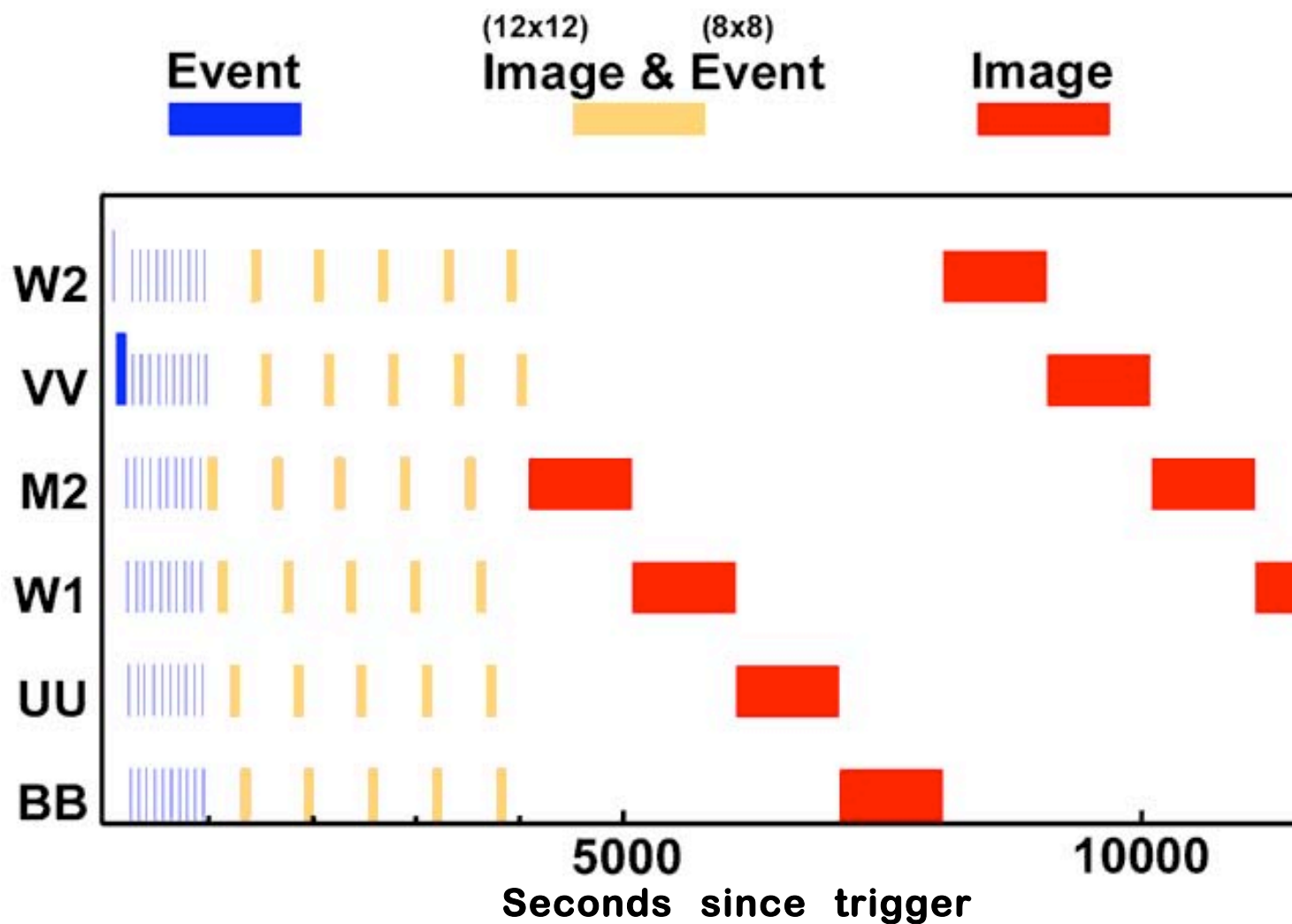




image file format



- ❑ There will be a maximum of 11 raw image files, one for each filter.
- ❑ Each file contains multiple image extensions. The extensions contain one image exposure in the sequence they were taken.
- ❑ Data taken in Event mode is extracted over RAWX and RAWY and added as extra extensions to the image file.
- ❑ Event mode data from Image&Event mode is similarly included if the windows of the Image and Event modes do not overlap.

fv: Summary of sw00000001001uvvraw.img in /local/data/isaac2/still/sw00000001001_burs

| File Edit Tools | | | | Help | | |
|-----------------------------|-------------|-------|-------------|--------|-------|-------|
| Index | Extension | Type | Dimension | View | | |
| <input type="checkbox"/> 0 | Primary | Image | 0 | Header | Image | Table |
| <input type="checkbox"/> 1 | vv93454240E | Image | 2048 X 2048 | Header | Image | Table |
| <input type="checkbox"/> 2 | vv93454427E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 3 | vv93454523E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 4 | vv93454619E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 5 | vv93454715E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 6 | vv93454811E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 7 | vv93454907E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 8 | vv93455003E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 9 | vv93455099E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 10 | vv93455195E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 11 | vv93455291E | Image | 720 X 720 | Header | Image | Table |
| <input type="checkbox"/> 12 | vv93455837E | Image | 480 X 480 | Header | Image | Table |
| <input type="checkbox"/> 13 | vv93455837I | Image | 721 X 721 | Header | Image | Table |
| <input type="checkbox"/> 14 | vv93456473E | Image | 480 X 480 | Header | Image | Table |
| <input type="checkbox"/> 15 | vv93456473I | Image | 721 X 721 | Header | Image | Table |



event file format



- ☐ There will be one raw event file per filter.
- ☐ Each file contains an EVENTS table extension containing events from all exposures during the observing sequence.
- ☐ A STDGTI extension is not possible because the science window may change from exposure to exposure.
- ☐ The EXPREF column in the EVENTS table points to a specific GTI extension in the file, one GTI extension per exposure.
- ☐ The WINDOW extension contains bookkeeping data for each exposure, i.e. start time and window size and location.

fv: Summary of sw00000001001ubbb2.unf in /local/data/isaac2/still/sw00000001001_burst/unfilte

| File Edit Tools | | | | Help | | | | |
|-----------------------------|-----------|--------|----------------------|--------|-------|-------|-----|--------|
| Index | Extension | Type | Dimension | View | | | | |
| <input type="checkbox"/> 0 | Primary | Image | 0 | Header | Image | Table | | |
| <input type="checkbox"/> 1 | EVENTS | Binary | 9 cols X 414313 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 2 | GTI1 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 3 | GTI2 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 4 | GTI3 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 5 | GTI4 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 6 | GTI5 | Binary | 2 cols X 2 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 7 | GTI6 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 8 | GTI7 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 9 | GTI8 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 10 | GTI9 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 11 | GTI10 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 12 | GTI11 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 13 | GTI12 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 14 | GTI13 | Binary | 2 cols X 1 rows | Header | Hist | Plot | All | Select |
| <input type="checkbox"/> 15 | WINDOW | Binary | 10 cols X 13 rows | Header | Hist | Plot | All | Select |



Level II processing



Image data

- ☐ Create bad pixel maps (uvotbadpix).
- ☐ Reduce mod-8 fixed pattern noise (uvotmodmap).
- ☐ Flat field images (uvotflatfield).
- ☐ Convert from raw coordinates to RA and Dec (swiftxform).
- ☐ Create exposure maps (uvotexpmap).

Event data

- ☐ Calculate RA & Dec and detector coordinates for each event (coordinator).
- ☐ Screen the data for orbital and astrometric contamination, bad pixels and compression damage (uvotscreen).



Level III processing



Image data

- ☐ Co-add images.
- ☐ Pass source detection algorithm over images (uvotdetect).
- ☐ Convert count rates to magnitude in source lists (uvotmag).
- ☐ Cross-correlate with GSC (uvotstarid).
- ☐ Create FITS tables and gif plots of magnitude history (uvotmaghis).
- ☐ Extract grism spectrum (uvotevgrism).

- ☐ Construct response matrices for spectra (uvotrmfgen).
- ☐ Create spectral gif plots.

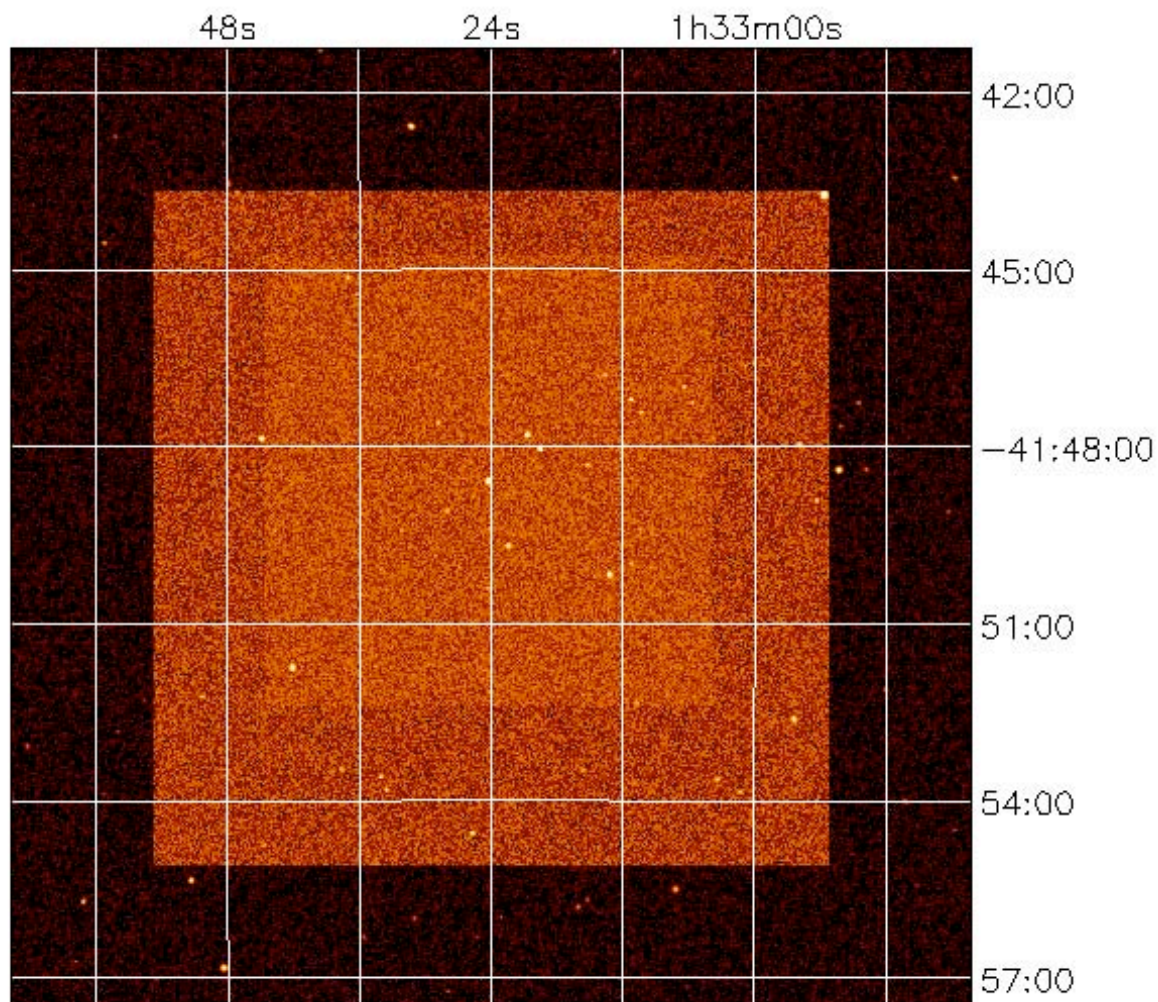
Event data

- ☐ Extract 11 ms time resolution light curves for the source (FITS and gif).
- ☐ For grism events, calculate wavelength of each photon and re-screen data.



Level III products: deep images *Swift*

Safe Pointing 1
SWIFT UVOTA 2003 Dec 18 Exposure: 400 s

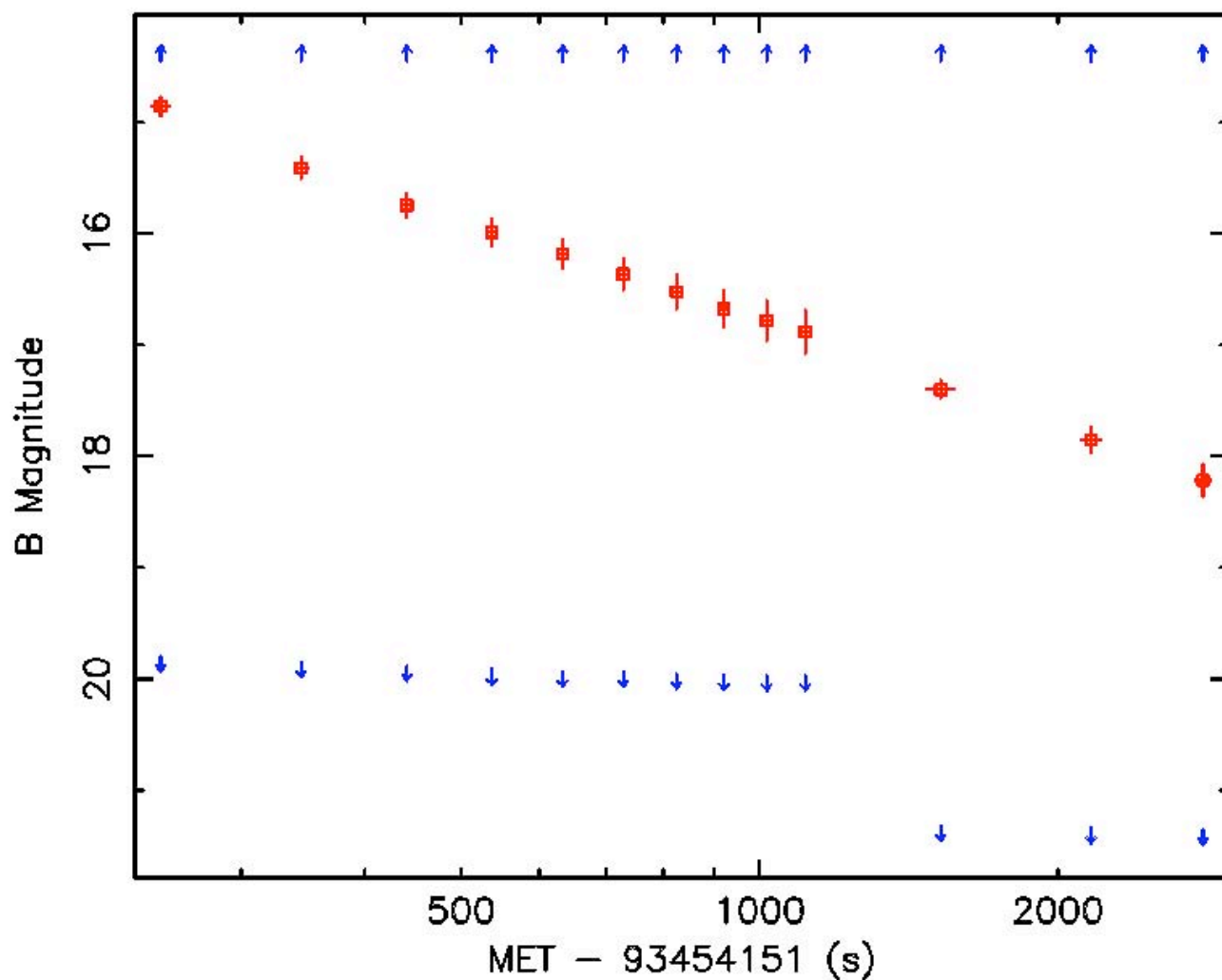




Level III products: decay curves

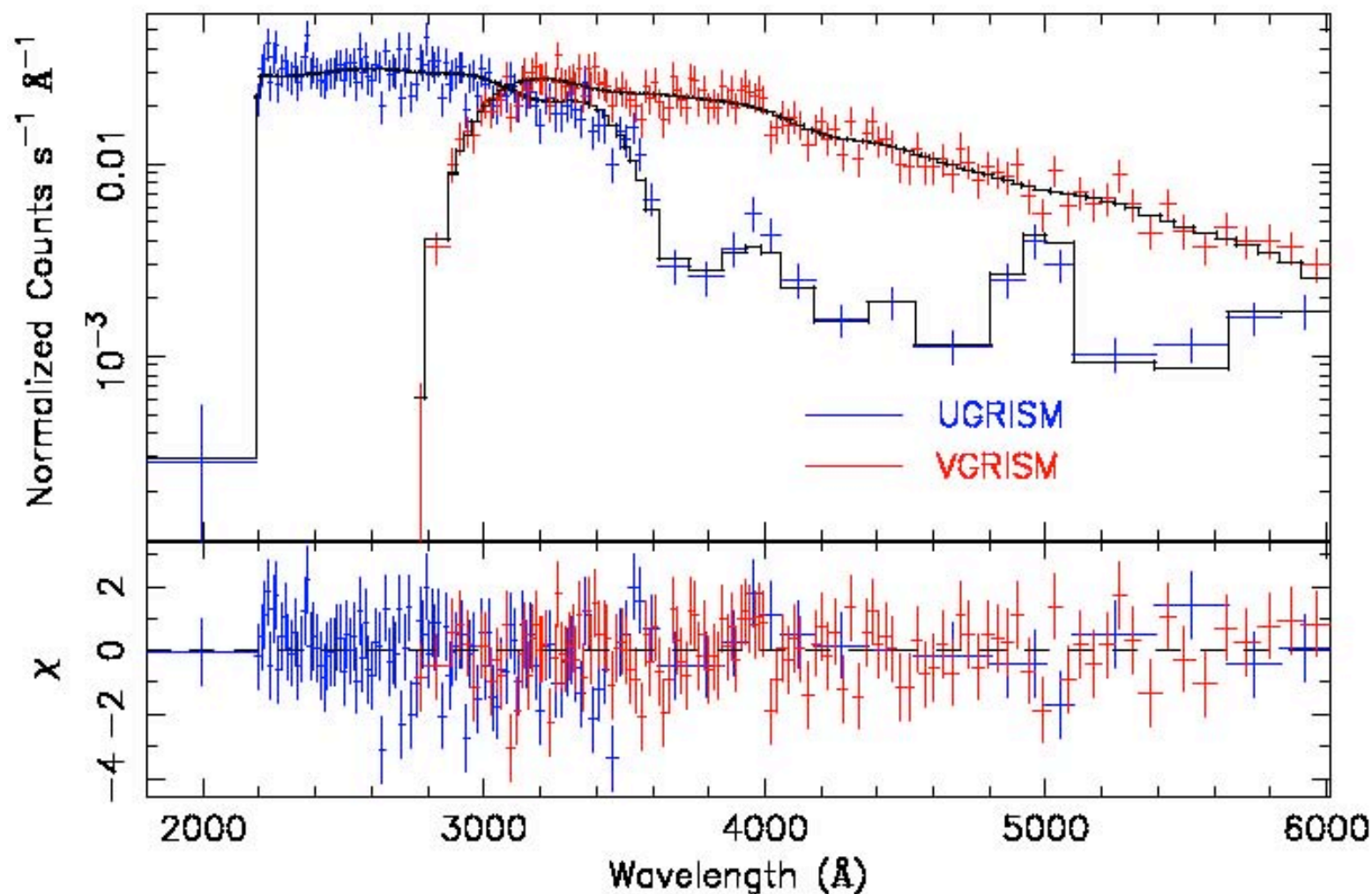


B magnitude vs time since trigger





Level III products: grism spectra





Burst Advocate Software



UVOT & Burst Advocacy



- ☐ Automated GCN UVOT software will provide none, one or many afterglow candidates.
- ☐ The role of the Burst Advocate will be to confirm or find the afterglow position:
 - ☐ quality-check GCN messages.
 - ☐ Inspect the Malindi data.
 - ☐ Archive afterglow properties position/magnitude/redshift using the AKBAR system.
- ☐ It would take many hours to perform these tasks manually. UVOT burst advocate software allows the BA to navigate the archive, detect and localize the afterglow, and fill the majority of AKBAR boxes autonomously.

Astrophysics Knowledge Base for Analysis and Reporting **AKBAR**

NASA's HEASARC: Archive

Verify

General

Target ID Source Name

Enter GRB name as: GRB_YYMMDD or GRB_YYMMDDn

R.A. Dec Error [arcmin] Position Flag Source is a GRB? Catalogued Source?

BAT Parameters

UVOT Parameters

UVOT General

UVOT On? Grism Used? UVOT Afterglow Detected? Afterglow in Grism Detected? Problems Affecting the UVOT Values in this Form? Problems Affecting Observation?

UVOT Position

R.A. Dec Error [arcmin] Filter Confusion Possible Lensing? Time when afterglow is first seen [s from Trigger]

UVOT Redshift Limits

Photometric

Filter / Min - Max Redshift

Spectral Lines

Minimum Redshift Maximum Redshift Transition Type

Intensity in Finding Chart Exposure

Start [s from Trigger] Exposure [s] Mag Error Upper Limit? Saturated Source?



Comparison with source catalogues *Swift*

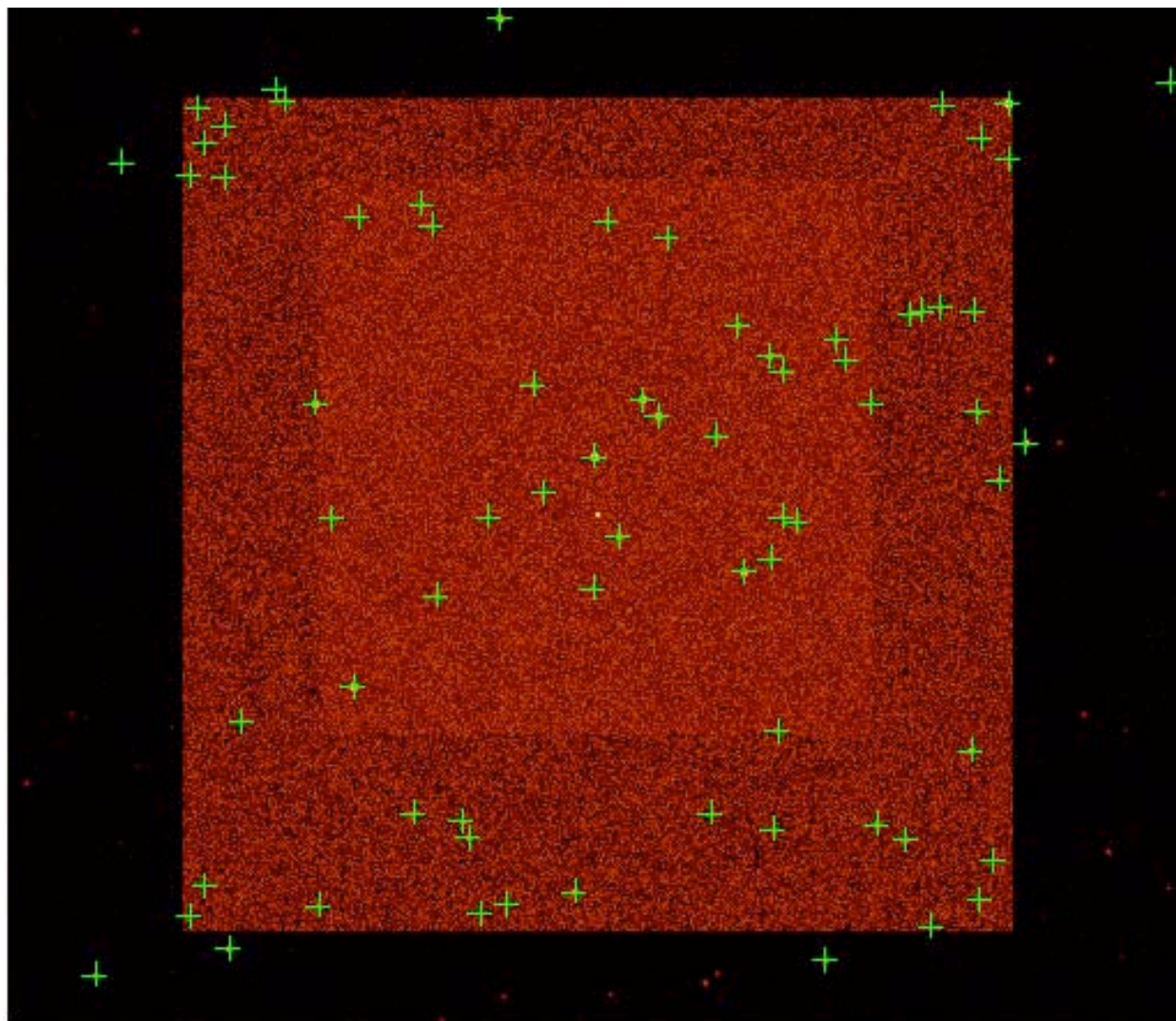
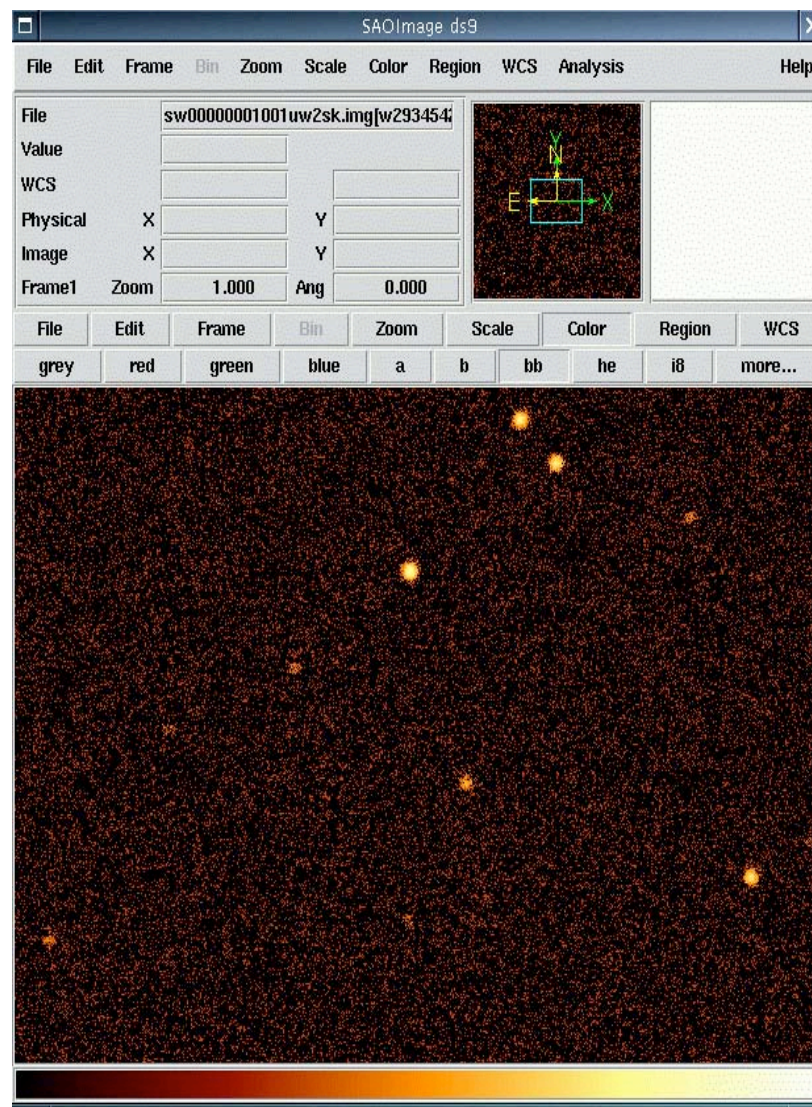
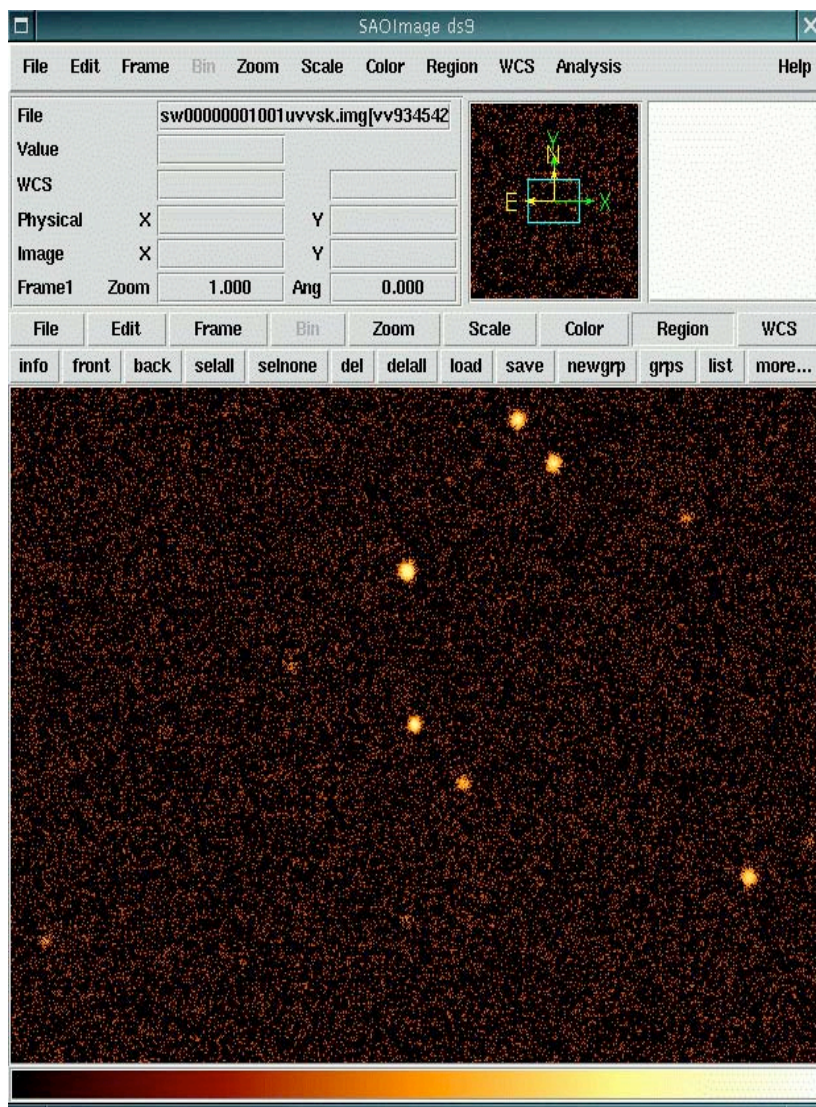




Image comparisons

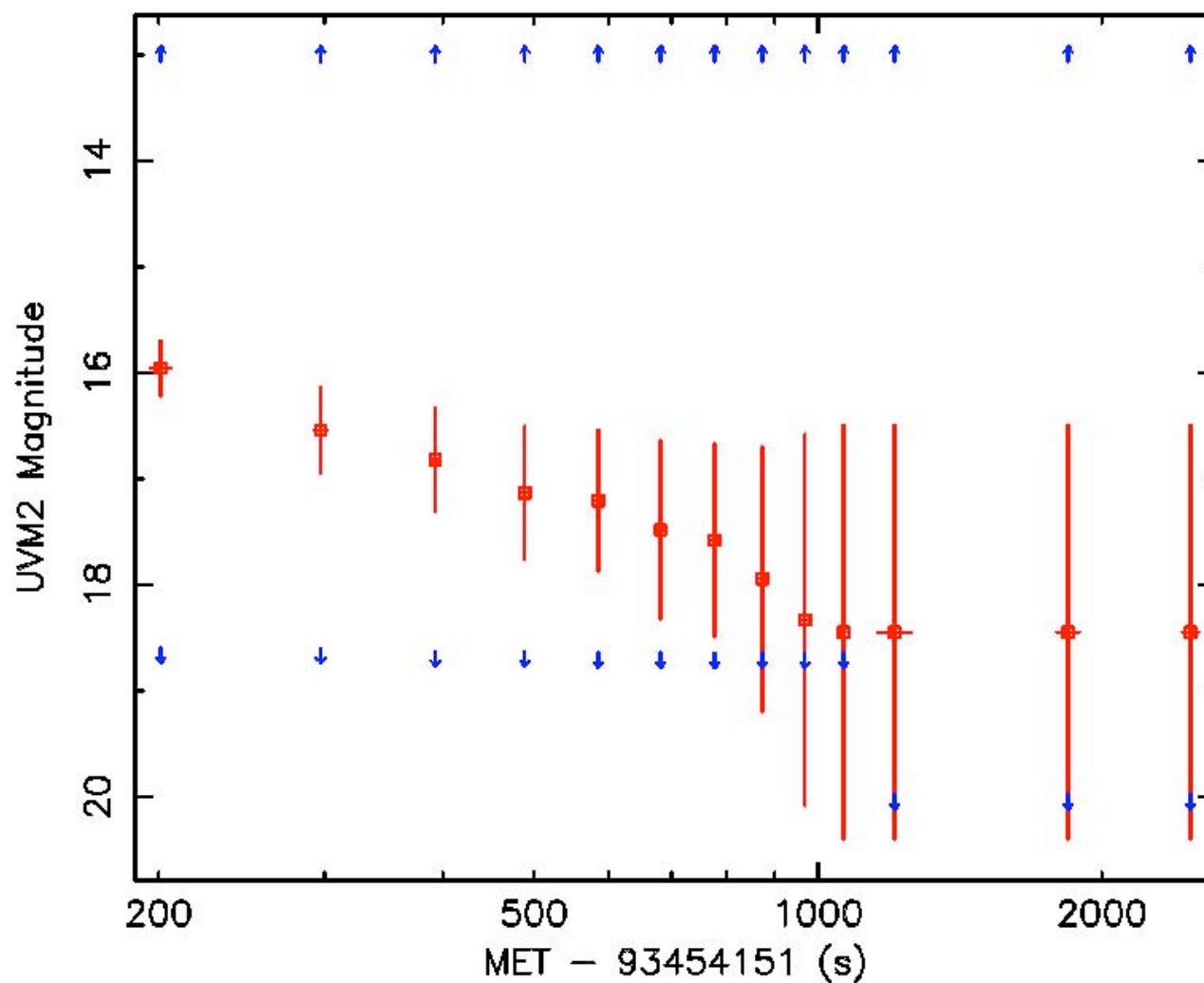




Aperture photometry

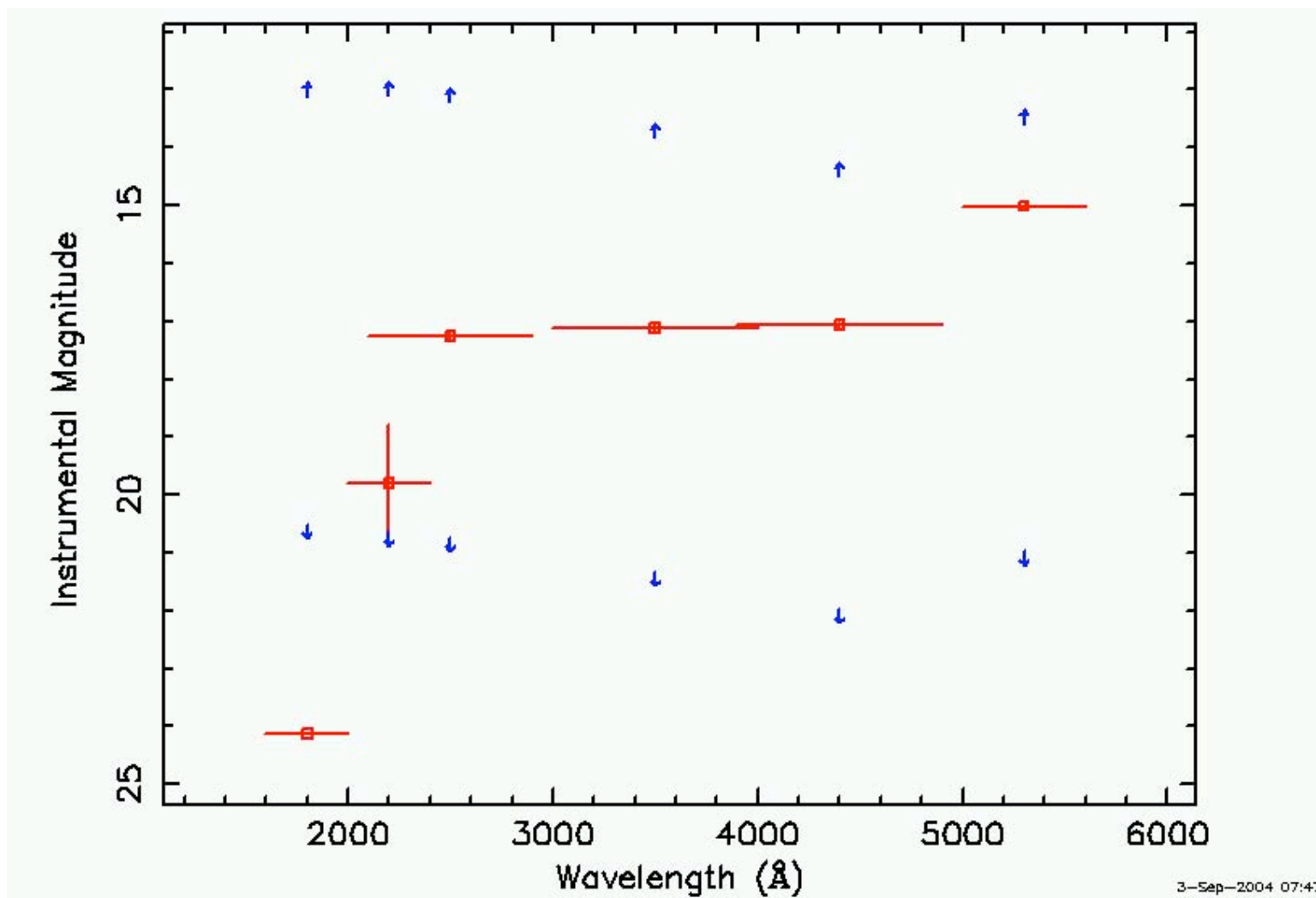


UVM2 magnitude vs time since trigger





Redshift





Summary



- ☐ UVOT software is 95% flight-ready.
- ☐ Development will obviously continue in to the mission.
- ☐ Feedback from the community will be solicited.